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6. AUTHOR(S) Peter Lurker				5d. PROJECT NUMBER	
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13. SUPPLEMENTARY NOTES					
14. ABSTRACT Headquarters Air National Guard Bureau Command requested the U.S. Air Force School of Aerospace Medicine provide modeling data of the maximum oxygen concentration aboard mobility aircraft used by the Air National Guard (C-130, C-5, C-17, KC-10, and KC-135) when transporting a liquid oxygen unit, the Mass Oxygen Distribution System (MODS-75). The AIHA Press mathematical model for estimating occupational exposure to chemicals was used to estimate the maximum oxygen level in the cargo compartment of the mobility aircraft (C-130, C-17, C-5, KC-10, and KC-135). The input variables to the model are the initial oxygen concentration, the volume of the aircraft in cubic meters, the ventilation rate of the cargo area in cubic meters per minute, and the emission rate of oxygen in milligrams per minute. Output of the model would be the oxygen level in milligrams per cubic meter (mg/m ³) over time. A worst-case scenario of 14 hours was used. The model was assessed with two pressures. The first was the operation of the aircraft on the ground, and the second was with an assumed pressurization of the aircraft at 8,000 feet equivalent altitude. The MODS-75 with liquid oxygen and up to 10 MODS-75 units will not exceed the maximum oxygen level of 23.5% inside all the aircraft assessed (C-130, C-17, C-5, KC-10, and KC-135).					
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DEPARTMENT OF THE AIR FORCE
USAF SCHOOL OF AEROSPACE MEDICINE (AFMC)
WRIGHT-PATTERSON AFB OH

28 November 2012

MEMORANDUM FOR HQ AIR NATIONAL GUARD BUREAU/SGAX
ATTN: MSGT SCOTT LARUE
3501 FETCHET AVE
JOINT BASE ANDREWS MD 20762

FROM: USAFSAM/OEC
2510 Fifth Street
Wright-Patterson AFB, OH 45433-7913

SUBJECT: Consultative Letter AFRL-SA-WP-CL-2012-0067, HQ Air National Guard
Bureau Request for Hazardous Materials Waiver per AFMAN 24-204 for
the MODS-75

1. INTRODUCTION:

a. *Purpose:* Headquarters Air National Guard Bureau Command CBRN Enhanced Response Force Advisor, MSgt Scott LaRue (HQ ANGB/SGAX), requested the U.S. Air Force School of Aerospace Medicine (USAFSAM) provide modeling data of the maximum oxygen concentration aboard mobility aircraft used by ANG (C-130, C-5, C-17, KC-10, and KC-135) when transporting a liquid oxygen unit, the Mass Oxygen Distribution System (MODS-75).

b. *Survey Personnel:* Dr. Peter Lurker, PE, CIH, USAFSAM/OECC

c. *Personnel Contacted:*

- (1) MSgt Scott LaRue, Command CBRN Enhanced Response Force Advisor, HQ ANGB/SGAX, Andrews AFB, MD
- (2) Mr. James Frank, Engineer, 401 SCMS/GUMAA, Air Force Packaging Technology and Engineering Facility, Wright-Patterson AFB, OH
- (3) Mr. James Brinkley, Essex Cryogenics, Sustaining Engineer, 8007 Chivvis, St. Louis, MO 63123

d. *Assessment Limitations:* The assessment was based on the limitation of the American Industrial Hygiene airborne concentration model used as well as the accuracies of ventilation rates and cargo volume of the various mobility aircraft that were provided in the previous consults done by the Armstrong Laboratory. While we have adopted the model to predict the effects of the reduced cabin pressure, the model will not predict the effects of rapid pressure change. Nor does the model predict the effects of turbulence on the release of oxygen from the MODS-75.

2. DOCUMENT REVIEW:

- a. Consultative Letter, AL/OE-CL-1997-0056, Transportation of Unvented PTLOX aboard C-21 Aircraft (Request from TSgt Blake dated 20 February 1997), 10 April 1997.
- b. Consultative Letter, 91-008EQ0017BGA, Transportation of Unvented PT LOX Units for MEDICAXC Purposes during Operation Desert Storm, 12 February 1991. Det 6 AL/EQ, Mr. Langwell, USAF Occupational and Environmental Health Laboratory (AFSC) Brooks AFB, TX.
- c. Consultative Letter, AL/OE-CL-1996-0294, Transportation of Unvented PTLOX Units on USAF Aeromedical Aircraft, Memorandum for AL/CFTS by Major Andrew MacCabe, Acting Chief Occupational Medicine Division, Armstrong Laboratory, 26 August 1996.
- d. Air Force Manual (AFMAN) 24-204, Preparing Hazardous Materials for Military Air Shipment, dated September 2009.
- e. Essex Cryogenics MODS Demo Longevity Testing Report, dated April 2010.
- f. American Industrial Hygiene Association (AIHA) Press, *Mathematical Models for Estimating Occupational Exposure to Chemicals*, Keil C, et al., 2000.

3. SURVEY PROCEDURES/DISCUSSION:

- a. AFMAN 24-204, Preparing Hazardous Materials for Military Air Shipment, dated 01 September 2009, paragraph 1.2.2.1, prescribes 401 SCMS/GUMAA as the Air Force focal point for determining what hazardous materials are authorized to be shipped on USAF military aircraft. If a particular item is not authorized in the attachments of this AFMAN, then the shipper (HQ ANG in this case with the MODS-75) must request a waiver from 401 SCMS/GUMAA. Once this waiver is issued by 401 SCMS/GUMAA, then the shipper can transport the MODS-75 on the mobility aircraft that HQ ANG had designated in the waiver request.
- b. Both HQ ANG (MSgt Scott LaRue) and the 401 SCMS/GUMAA (Mr. James Frank) agreed to accept the gaseous oxygen emission rate developed by Essex Cryogenics of their MODS-75. Mr. James Brinkmeyer of Essex provided a detailed report showing about 35 days of testing. The average loss over the 35-day period was used, and 4.35 pounds of oxygen were off-gassed per day.
- c. The AIHA Press mathematical model for estimating occupational exposure to chemicals was used to estimate the maximum oxygen level in the cargo compartment of the mobility aircraft (C-130, C-17, C-5, KC-10, and KC-135). There were two ventilation rates reported for the KC-135. The input variables to the model as seen in the attachment are the initial oxygen concentration, the volume of the aircraft in cubic meters, the ventilation rate of the cargo area in cubic meters per minute, and the emission rate of oxygen in milligrams per minute. Output of the model would be the oxygen level in milligrams per cubic meter over

time. A worst-case scenario of 14 hours was used. The model was assessed with two pressures. The first was the operation of the aircraft on the ground, and the second was with an assumed pressurization of the aircraft at 8,000 feet equivalent altitude.

4. FINDINGS:

a. The predicted maximum released oxygen concentration, in percentage, of the MODS-75 unit is provided in Table 1.

Table 1. Predicted Maximum Oxygen Level in Aircraft with the Essex Cryogenics MODS-75

Aircraft	Volume (m ³)	Ventilation Rate (m ³ /min)	Oxygen Level (%) for 1 MODS-75 at Ground Level	Oxygen Level (%) for 1 MODS-75 at 8,000 ft	Oxygen Level (%) for 10 MODS-75s at 8,000 ft
C-130	169	24.5	20.9	22.2	22.3
C-17	1207	28.3	20.9	21.9	22.0
C-5	1839	6.1	20.9	20.0	20.1
KC-10	340	34	20.9	21.8	22.2
KC-135	1557	2.6	20.9	21.3	20.6
KC-135	1557	6.5	20.9	20.4	20.6

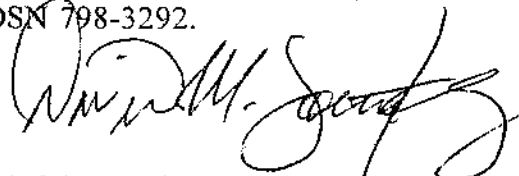
Assumptions:

1. Mod-75 filled with liquid oxygen off-gassing at 4.35 pounds per day of oxygen (reported oxygen emission rate during Essex Cryogenics, Inc. testing).
2. On the ground, atmospheric pressure was assumed, and for flight, an assumed cabin pressure of 8,000 feet equivalent oxygen levels was used in the AIHA Press model 198 predicting the oxygen concentration in the cargo compartment.
3. Ambient oxygen level is at 20.9%.
4. Oxygen concentration at time zero is 20.9%.
5. Limit is 23.5% oxygen in aircraft based on Occupational Safety and Health Administration confined space entry.
6. Predicted 14-hour flight as worst-case scenario.
7. The 26 Aug 1996 Armstrong Lab CL, Transport of Unvented NTLOX Units on USAF Aeromedical Aircraft, reported two ventilation rates for the KC-135: 5,500 ft³/h (2.6 m³/h) and 13,750 ft³/h (6.5 m³/h).

b. None of the estimated maximum oxygen concentrations for ground operations or aircraft operations at the equivalent pressure of 8,000 feet yielded results in excess of the Occupational Safety and Health Administration maximal oxygen concentration of 23.5%. This was the same whether using a single MODS-75 unit filled with liquid oxygen or as many as 10 MODS-75 units transported in each of the aircraft evaluated (C-130, C-17, C-5, KC-10, and KC-135).

5. CONCLUSIONS: Based upon the limitations and assumptions stated earlier in this assessment, the MODS-75 with liquid oxygen and up to 10 MODS-75 units will not exceed the maximum oxygen level of 23.5% inside the all aircraft assessed (C-130, C-17, C-5, KC-10, and KC-135).

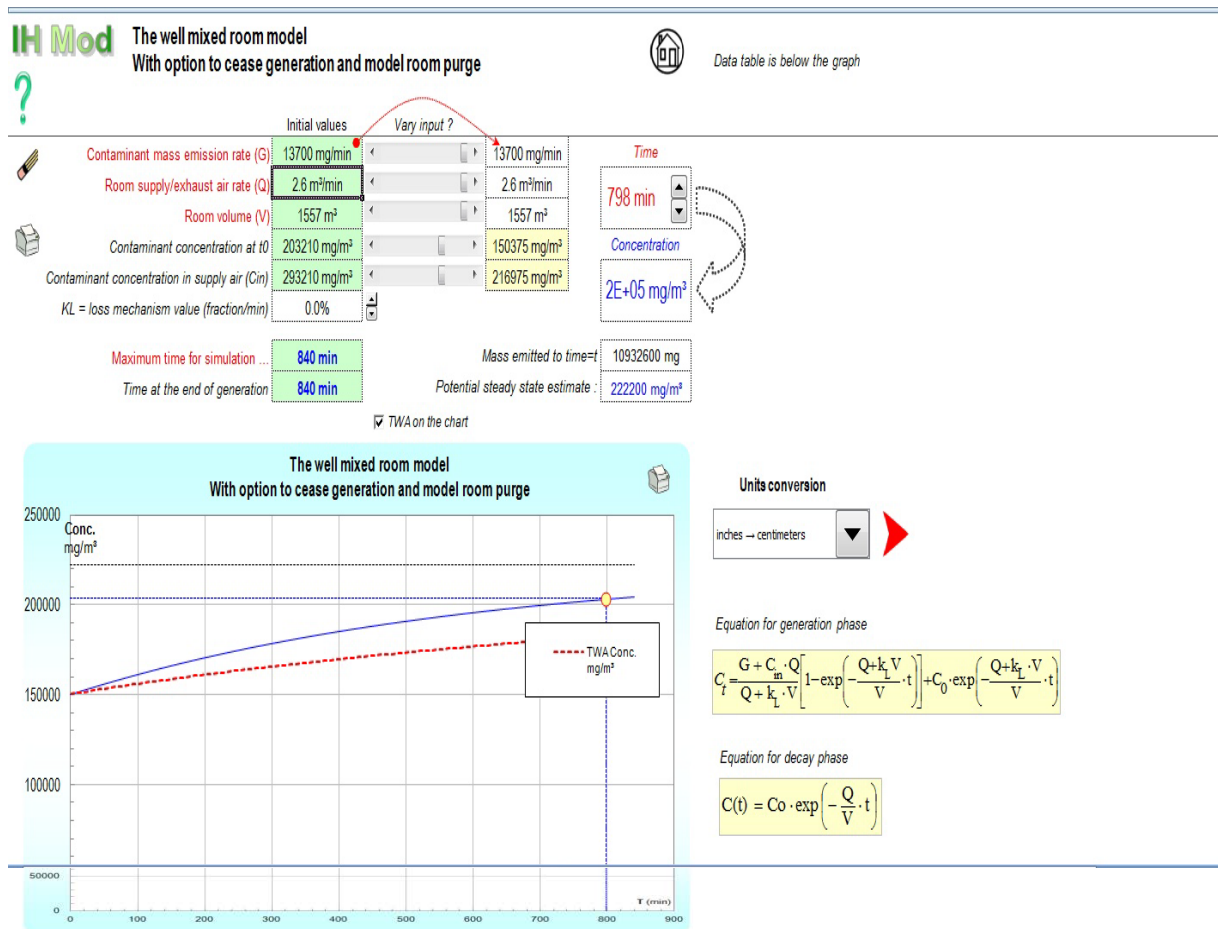
6. Thank you for affording USAFSAM/OEC the opportunity to assist you. Please direct additional questions to Dr. Peter A. Lurker, DSN 798-3292.

A handwritten signature in black ink, appearing to read "David M. Sonntag", is written over the typed name below.

DAVID M. SONNTAG, Lt Col, USAF, BSC
Chief, Consultative Services Division

Attachment:
Snapshot of the AIHA Press Oxygen Concentration

Attachment Snapshot of the AIHA Press Oxygen Concentration



Notes:

1. G, the emission rate, is converted from 4.35 pounds per day to 1,370 mg/min for one MODS-75. Shown in the snapshot is the emission rate for 10 MODS-75s or 13,700 mg/min.
2. Q, room supply/exhaust air rate, is the same as the ventilation rate. The value of 2.6 m³/min is for the KC-135 at its lower ventilation rate.
3. V, room volume, is the volume of the cargo compartment.
4. The contaminant concentration at t₀ is the initial oxygen concentration at time = zero. For this example, we are using the oxygen concentration at 8,000 feet altitude. This was derived as follows:
 - a. The conventional formula to convert from mg/m³ to PPM is as follows: $\text{mg/m}^3 = \text{MW} \times \text{PPM} / 24.45$, which is only good at 1 atm and 25 °C.
 - b. The molar volume of 24.45 is the volume in liters of one gram mole of vapor at 1 atm and 25 °C. To calculate the molar volume at a different temperature and pressure use $V_m = RT/P$, where R = universal gas constant = 62.4, T = temperature (T deg C + 273), and P = pressure in mm HG.
 - c. $\text{mg/m}^3 = \text{MW} \times \text{PPM} \times P / RT$.

- d. At 8,000 feet equivalent altitude, the pressure is 10.91 psi or 565 mmHg.
 - e. Therefore, at 8,000 feet equivalent altitude, $\text{mg/m}^3 = 32 \times 565 \times \text{PPM} / 62.4 \times 298 = 0.9723 \text{ PPM}$.
 - f. 20.9% oxygen is equal to $0.209 \times 10^6 \text{ PPM}$; therefore, $C_o = 0.9723 \times 0.209 \times 10^6 \text{ PPM} = 203,210 \text{ mg/m}^3$.
5. The oxygen concentration is plotted over the 14-hour flight in mg/m^3 . The maximum oxygen concentration was converted back to the percent of oxygen and reported for each aircraft type in Table 1.